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ENVIRONMENTAL DATA BASE FOR REGIONAL STUDIES IN THE HUMID TROPICS

Report No. 5

Edward E. Garrett (editor), et al

Semiannual Report No. 5

March 1969

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UNITED STATES ARMY TROPIC TEST CENTER

Sponsored by

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Report Period: 1 September 1967 through 29 February 1968

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This research was supported by the Advanced Research Projects Agency of the Department of Defense and by the Army Research Office, OCRD, Department of Army.

Conducted By

US Army Test and Evaluation Command
US Army Tropic Test Center, Fort Clayton, Canal Zone
with assistance of Weather Engineers of Panama Corp.
Contract DAHB01-67-C-B239

March 1969

FOREWORD

This summary report, the fifth of a series to be issued semiannually, covers the progress and status of the Environmental Data Base for Regional Studies in the Humid Tropics. The project is sponsored by the Office, Secretary of Defense, Advanced Research Projects Agency (ARPA), Directorate of Remote Area Conflict, and by the Department of Army, Office of Chief of Research and Development, Army Research Office (ARO).

The study reported herein is being conducted under the guidance and with the direct participation of the Research Division of the US Army Tropic Test Center. Commanding Officer during the report period was Colonel John Zakel, Jr. The research program is carried out under the supervision of Dr. Guy N. Parmenter, Chief of the Division. The following individuals of the Research Division staff have been responsible for preparing the technical portions of the report; as noted: Dr. Thomas C. Crebbs, Mr. George Gauger, Mr. Alfredo Gonzalez, Dr. Robert S. Hutton, and Dr. Wilfried H. Portig. Mr. Michael A. Fradel is the Project Officer and has direct responsibilities in the meteorological field and for data processing. The compilation, arrangement, and editing of the report has been handled by Mr. Edward E. Garrett, Physical Environmental Scientist of the Division.

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SUMMARY

This fifth semiannual progress report on the Environmental Data Base Project contains a brief background of the project, its objectives, approach, and sites of operation, and presents a summary of activities for the period September 1967 through February 1968, with some analyses and syntheses of selected data.

The Climate section (Part III) presents an analysis of the Wet Bulb Globe Temperature data.

The Soils and Hydrology section (Part IV) presents a summary of the data collected at the Fort Kobbe Satellite site.

The Vegetation section (Part V) contains a discussion and description of the utility of individual plant species as indicators of forest succession and development.

The section on Microbiology and Chemistry of the Atmosphere (Part VI) presents a discussion of the role played by microorganisms in the modification of chemical contaminants of the atmosphere and their potential effects on materials exposed to the environment.

ENVIRONMENTAL DATA BASE FOR REGIONAL STUDIES IN THE HUMID TROPICS

PART I. INTRODUCTION

Background

This fifth semiannual report covers project activity for the period from 1 September 1967 through 29 February 1968. The project is sponsored jointly by the Advanced Research Projects Agency, Office of the Secretary of Defense, and by the Army Research Office, Office of the Chief of Research and Development, Hqs., Dept of Army. The work has been performed by the US Army Tropic Test Center, US Army Test and Evaluation Command, Army Materiel Command, with contractual support of Weather Engineers of Panama, Corp. Additional scientific support was provided through the cooperation of the National Center for Atmospheric Research and other individual scientists.

The project calls for an interdisciplinary investigation of the humid tropical environments of the Canal Zone, which include a high rainfall region on the Atlantic slope of the isthmus where tropical evergreen broadleaf forests prevail and a relatively drier region with a more pronounced dry season on the Pacific slope where tropical semievergreen forests predominate. These areas are analogous to environments in regions of tropical monsoon and tropical savanna climates in southeast Asia and other parts of the tropics.

Project Objectives and Description

Objectives

The overall objective of the Data Base project is to provide increased knowledge concerning the militarily significant environmental factors of humid tropical environments. The project is designed to provide a bank of information and analyses derived from observations of selected physical and biological conditions at representative sites in the natural environments mentioned above. A specific objective of the US Army Tropic Center is to obtain detailed information concerning the environments in which its tests are conducted, which information will be of direct value in the planning and accomplishment of tests as well as in the development of tropical test techniques and methods. The project will establish, at the sites chosen as representative of the specified environmental regimes, the spatial and temporal variations of a number of natural conditions that affect the durability and operability of materiel as well as such factors as movement, communication, visibility, and the physical performance of troops.

Scope

The basic program for the Data Base project provides for interrelated investigations in the following fields: (1) Climate, specifically the

meteorological phenomena manifested below a height of approximately 50 meters; (2) Soils and hydrology, with emphasis on factors related to soil trafficability and ground water; (3) Vegetation, with emphasis on taxonomy, foliage canopy, plant succession, and the ground accumulation of forest debris; (4) Microbiology, with emphasis on numbers and kinds of bacteria and fungi and their transportation and deposition; (5) Macrofauna, currently limited to selected arthropods; and (6) Atmospheric chemistry, i.e., chemical and physical contaminants of the air.

Observational Approach

In order to demonstrate the relationships existing between the environmental factors given above, investiga ions are carried out synchronously at the chosen sites. These locations, because of funding and manpower limitations, are currently limited to two "main" sites, both in the Pacific region of lower and more seasonal rainfall. Site locations are planned for the Atlantic region, if funding permits, where rainfall is heavier and less distinctly seasonal. Additional "satellite" sites have been established in the Pacific region, where restricted data have been collected.

The project plan calls for the establishment of paired main sites in each climatic zone, one site being under and within a typical forest canopy the other in an open area subject to the same climatic influences. This "paired site" approach has been followed since the various environmental factors differ markedly (within forested and cleared areas). Furthermore, both forest and open areas occur extensively throughout the humid tropic regions, and they impose significantly different limitations on military activities.

The "main" sites are equipped with towers in order that temporal simultaneity may be matched with coordinated measurements throughout the vertical plane for both the climatic and the atmospheric chemical and biological fields. These include the standard meteorological parameters as well as sample determinations of atmospheric particulates and trace chemicals, airborne and surface-deposited microorganisms, and flying insects.

Some observations are made by Tropic Test Center personnel, however, most of the routine work is carried by contractual arrangement. During the period of this report the contract was held by Weather Engineers of Panama Corp. At the end of the period the contract terminated, and preparations were made for a new contractor to carry on the work at the beginning of March 1968. Project scient sts on the Tropic Test Center staff monitor all work and provide necessary guidance. The frequency of observation varies with the parameter measured, ranging from continuous reading, and/or automatic recording, of some meteorological instruments to the one-time observation of some soil factors.

PART II. OBSERVATION SITES

Site Locations

Established Sites

Two main observational sites are in current use. They are located on the Pacific side of the Canal Zone, which is characterized by a mean annual rainfall of approximately 70 inches, a pronounced dry season, and semievergreen forest vegetation. The two sites are located in the Albrook Forest and at Chiva Chiva (see Figure II-1). The former is in a forest with a relatively dense canopy and understory vegetation; the latter is in an open, grassy area about four kilometers westward. One satellite site located at Fort Kobbe is utilized for observation of soils and limited meteorological data.

Proposed Sites

The installation of paired main sites in the Atlantic environment is planned for the future. Here a much higher precipitation (130 inches annual mean rainfall) and a wetter "dry" season contribute to a forest with tropical evergreen characteristics and higher and denser canopies. Specific sites have been chosen within the Coco Solo Naval Ordnance Annex.

Site Descriptions

The two main sites are each equipped with 46-meter walk-up towers. Physical descriptions of the sites with their installations have been given in some detail in the previous Data Base Semiannual Reports[1,2,3*] and will not be repeated here. The instrumental arrays for the towers and the ground installations have been modified and are currently as shown on Figures II-2, -3 and -4. The top of the forest canopy at the Albrook Forest Site has grown upward appreciably since the last reporting period.

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* References cited are listed at the end of this report.

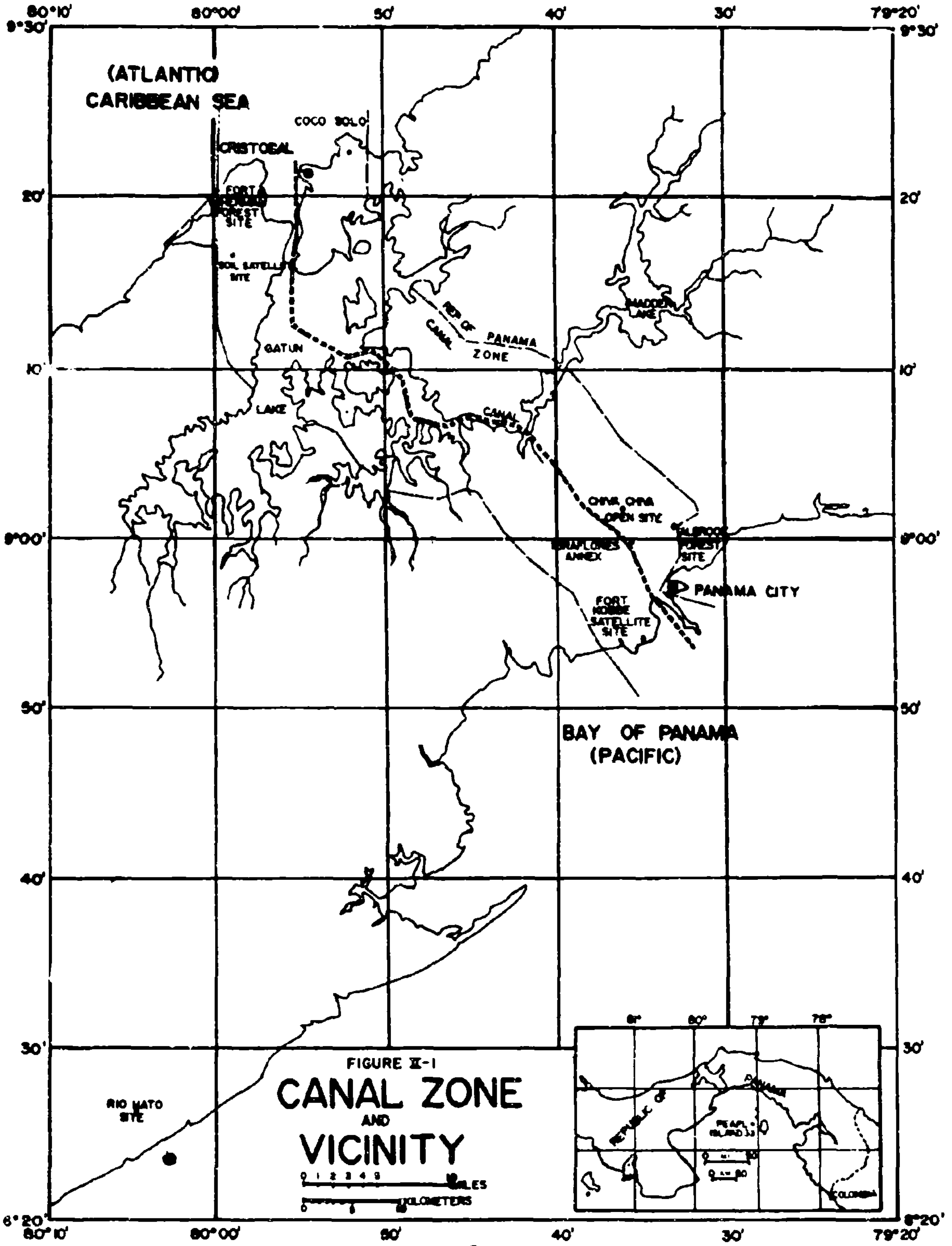

FIGURE X-1
CANAL ZONE AND VICINITY

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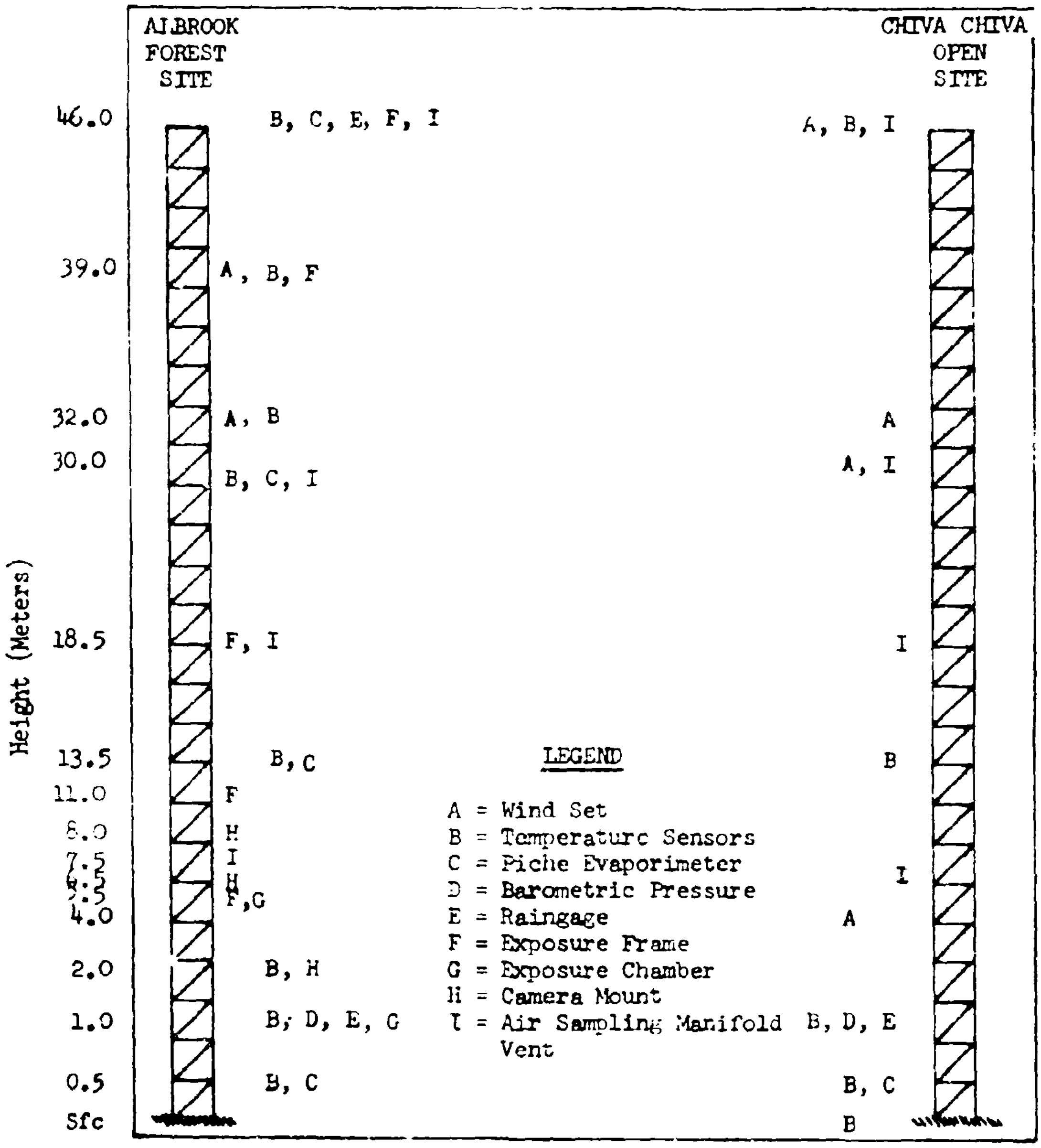

FIGURE II-2. INSTRUMENTATION ARRAY ON OBSERVATION TOWERS

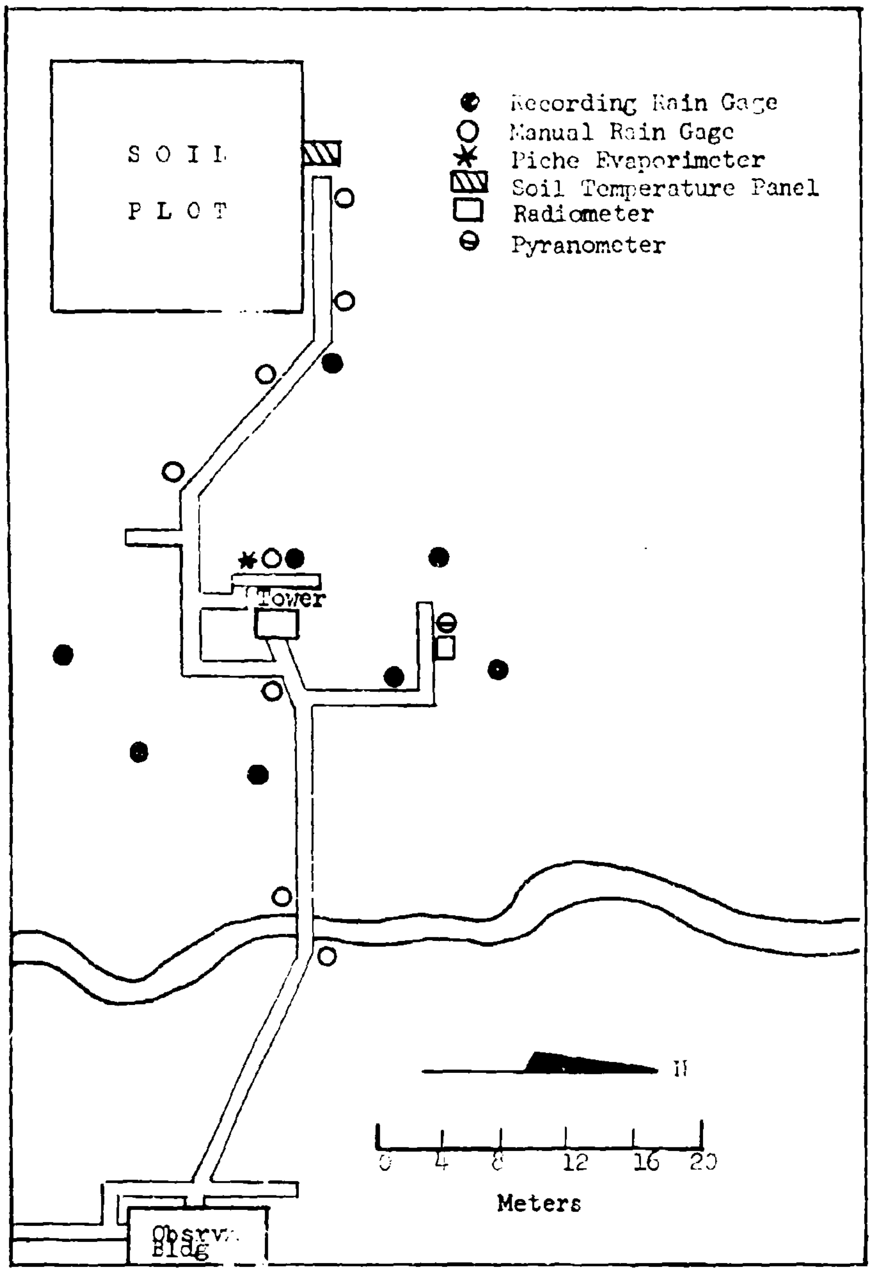

FIGURE II-3. ALBROOK FOREST SITE, GENERALIZED PLOT

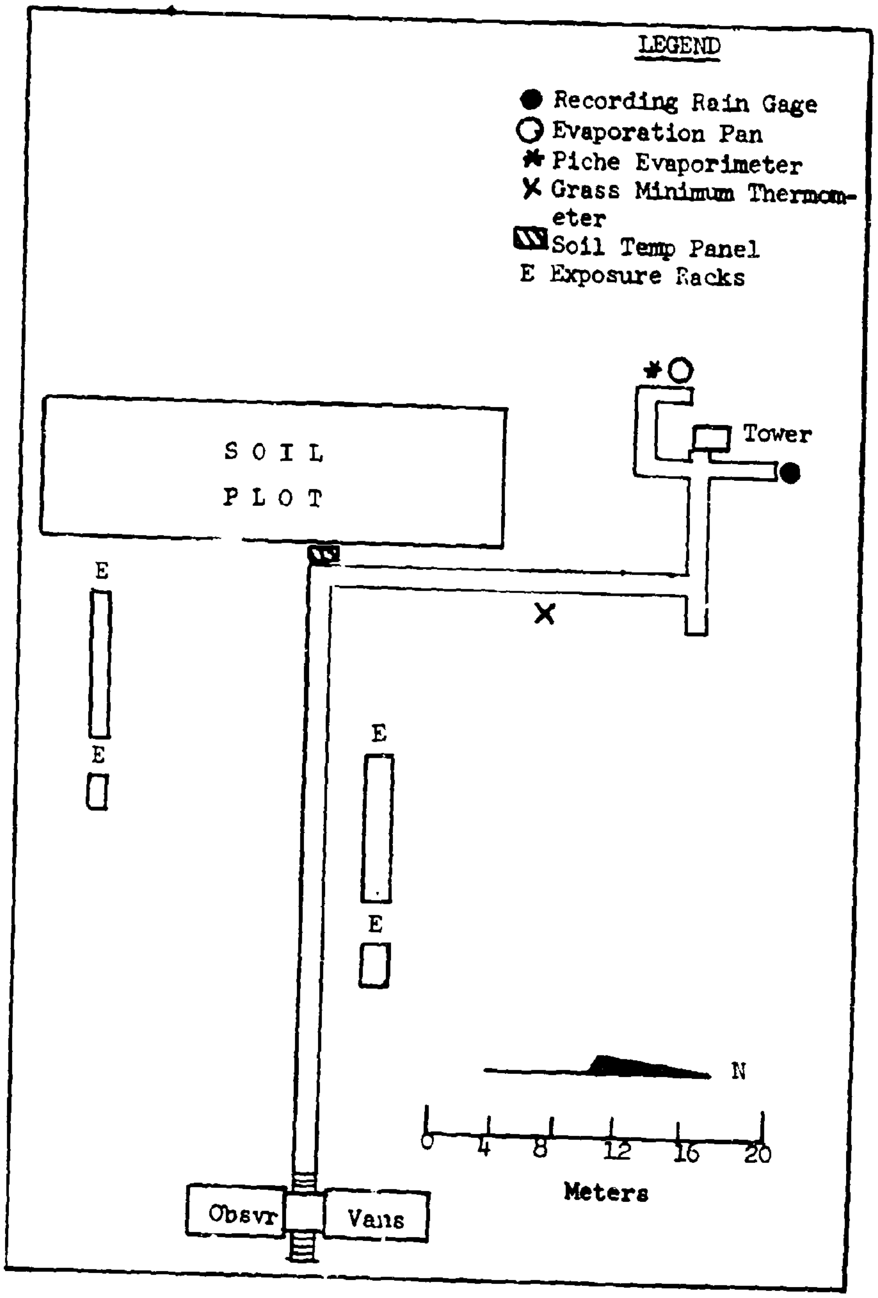

FIGURE II-4. CHIVA CHIVA OPEN, GENERALIZED PLOT

PART III. CLIMATE

Introduction

The climatic subtask of the Data Base project currently provides detailed information of the micrometeorological features existing in the semievergreen environment of this particular region of the tropics. Measurements are made through both the vertical and horizontal planes at selected sites; one in a forest and the other in a nearby cleared area. In addition to contributing to development of test methodology and techniques, the data obtained will be made available to other interested agencies for application to their own particular needs.

Observations

Routine observations continued throughout this report period except for the discontinuance of WBGT, Dew, and Stem Flow measurements. The WBGT data were considered sufficient for analytical purposes; the latter were determined to be not representative or realistic. Additionally, the number of locations was reduced due to instrument deterioration, with replacements dependent upon the final installation of the Automatic Data Acquisition Systems.

Funding limitations dictated a major change of contractual requirements with the automatic systems as the focal point. Consequently, very few observations were made during the month of February, a transitional period for adaptation to new techniques and a new contractor.

Instrumentation

Standard instrumentation continued in use throughout this period. Installation of the automatic system at the Albrook Forest site was completed and placed in operation during the month of February. Component deficiencies delayed the operational establishment of the system at the Chiva Chiva site. Figure III-1 is a view of the recording system at the Albrook Forest site building.

Data Reduction and Storage

Routine data reduction and storage techniques were continued (see previous Semiannual Report[3], p. 18). The availability of equipment and techniques are being studied so that the data presently stored on punch cards may be transferred to magnetic tape or magnetic disks. The last of the series of Monthly Microclimatic Studies was published for January 1968. A new series is planned for the future.

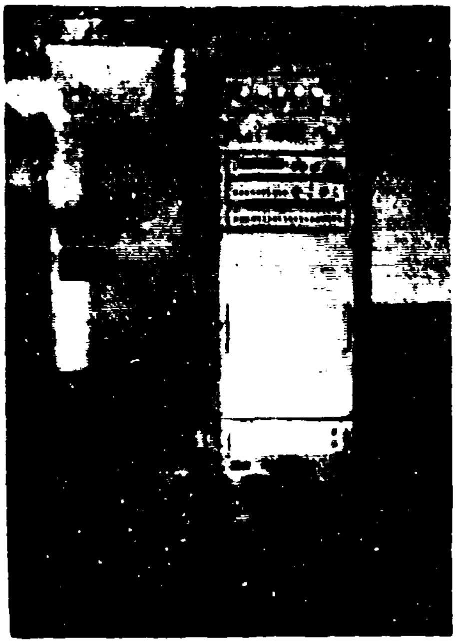

FIGURE III-1. VIEW OF THE AUTOMATIC DIGITAL RECORDING SYSTEM IN THE ALBROOK SITE.

Wet Bulb Globe Temperature*

Introduction and Background

It has long been known that man's ability to work and his comfort are affected by a complex of climatic elements which act in concert, rather than through any one element alone. Many different attempts have been made to define an "effective temperature". An especially promising definition was elaborated by C. P. Yaglou in 1957[4], and since then propagated by D. Minard[5,6]. Yaglou defined the Wet Bulb Globe Temperature (WBGT) as 1/10 dry bulb temperature (DB) plus 7/10 wet bulb temperature (WB) plus 2/10 black globe temperature (BG): WBGT = 0.1 DB + 0.7 WB + 0.2 BG. The resultant index is expressed as a temperature in degrees F. The black globe is supposed to simulate the effects of radiation and wind on the human body. It is a hollow copper ball, painted black, which is freely exposed to sun and wind. The interior temperature is measured by a thermometer with the bulb in the center of the ball and the scale extending outside. The dry bulb thermometer measures the temperature of the air at the instrument which in the case of wind is equal to the ambient temperature but which may differ in calm conditions. This thermometer is an ordinary mercury-in-glass instrument. The wet bulb thermometer is of the same type but its bulb is wrapped with a constantly moistened wick. It simulates the evaporative effects from the human skin. Figure III-2 shows an installation of the complete instrumentation.

Although the three components of the WBGT index are temperatures, and although the index is expressed in temperature units, it does not represent any real physiological temperature. Rather it is correlated to physiological and psychological reactions to heat stress. This correlation has not yet been fully explored. A basic discrepancy between the index and the effects on the human body will be mentioned below which precludes strict parallelism in the correlation.

As an integration of ambient temperature, moisture, wind, and radiation the WBGT represents fairly well the strain of a warm climate on man. (Those who developed the instrument intended to compare the effects of a hot, dry climate with the effects of a warm, humid one. The critical values are supposedly the same.) The critical value for a human being depends, of course,on the kind and degree of his activity, the garments he wears, and on his individual physiological reactions. It is presumed that if such conditions are equal the WBGT index will correlate with the effect of the climate on the well-being of personnel; increasing values indicate more discomfort or even danger. While it is up to the physiologists to establish critical WBGT values, the Environmental Data Base Project has

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* This section has been prepared by Dr. Wilfried H. Portig, Research Meteorologist.

established a climatolog[illegible] basis by determining the WBGT index every daytime hour (and for some m[illegible]s, every nighttime hour) at the open site as well as in the forest. A total of 27,360 WBGT measurements have been transferred to punch cards. The following discussion present some basic results. More detailed statistical study is planned for the future, which will supplement and expand, [illegible] not alter, the results described here.

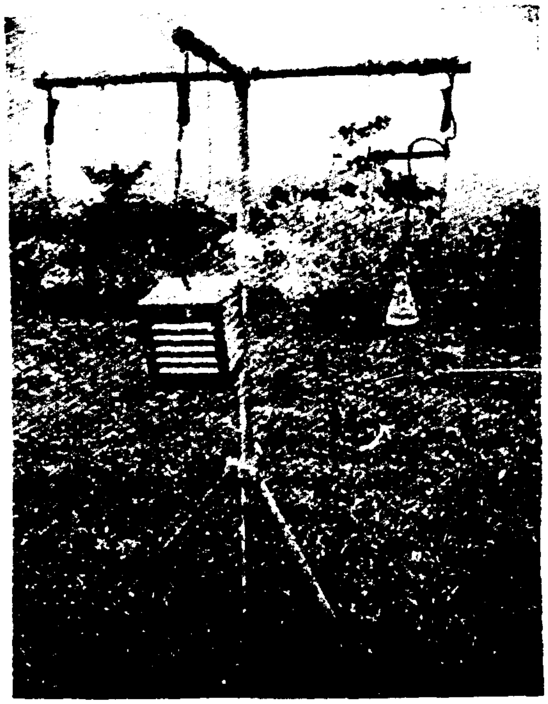


FIGURE III-2. INSTRUMENT FOR THE MEASUREMENT OF THE WET BULB GLOBE TEMPERATURE. (The mercury-in-glass thermometers have been replaced with thermistors for remote reading).

Data Analysis

Figure III-3 shows the diurnal and seasonal variation of the WBGT index excluding the hours from 2000 through 0500. This exclusion is justified by the fact that the nocturnal mean values are practically equal throughout the entire year, and that the WBGT index is designed to indicate the stress of the high temperatures rather than the chill of the night. It was noted during the course of the computations that the mean values for the same hour and the same month of subsequent years differed by up to 2°F. This is in agreement with other temperature measurement obtained with other instruments and represents actual differences between succeeding years. The following features are demonstrated by Figure III-3: a) The diurnal range of the WBGT index is lower in the forest (10°F) than in the open (16°F).

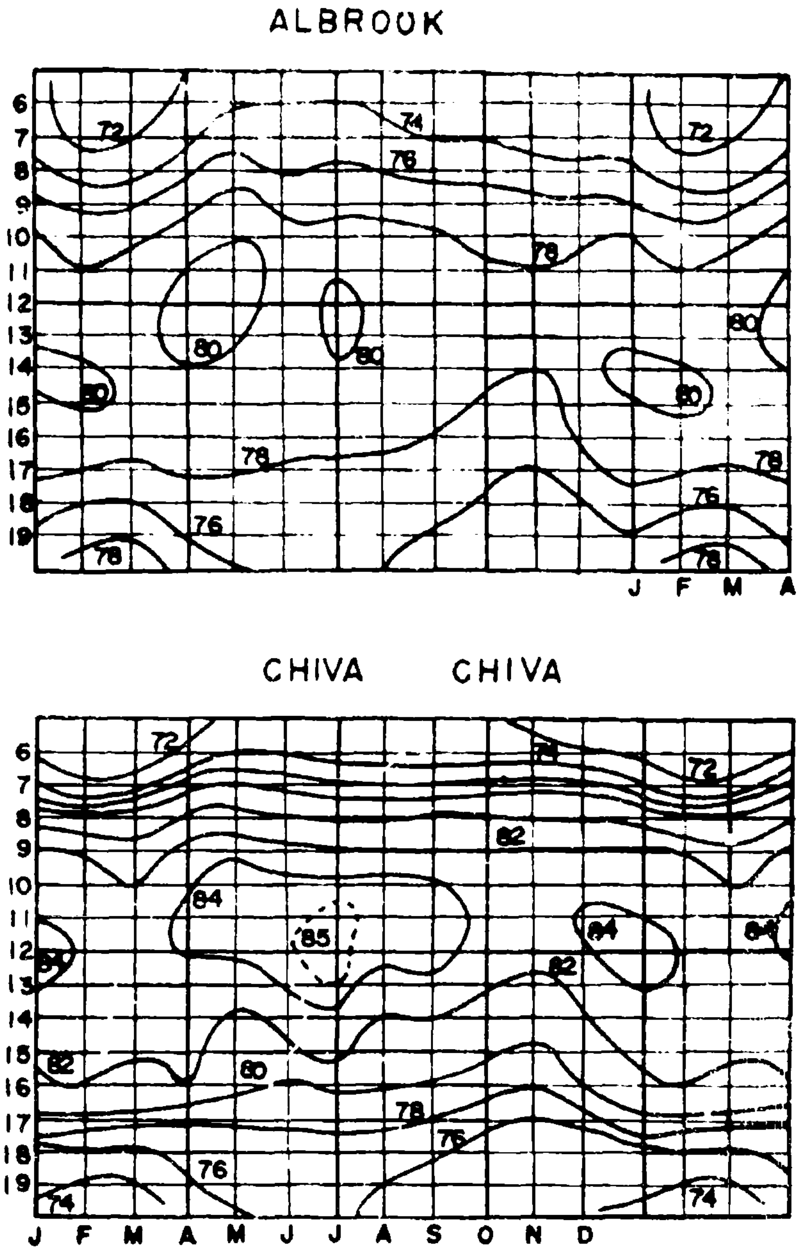


FIGURE III-3. ISOPLETHS OF WBGT INDEX, in °F

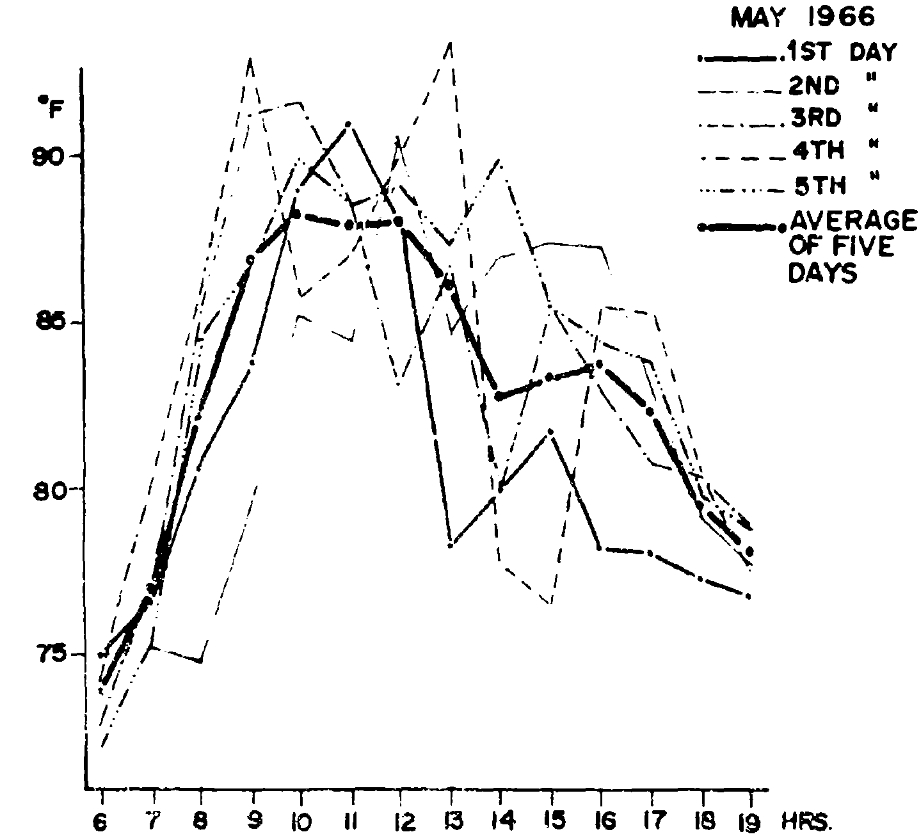
VERTICAL SCALE: HOUR OF DAY
HORIZONTAL SCALE: MONTHS

This difference is almost completely due to differing noon temperatures while the temperatures just before sunrise and after sunset are almost equal at both sites. b) The highest values occur in the open area one or two hours earlier than in the forest. To a certain extent this is a peculiarity of this region because the air is always moist enough, even in the dry season, to intensify the cloudiness at noon. These clouds screen the sunshine and produce a decreasing black globe temperature. In the forest where there is little or no sunshine, the formation of clouds has little influence on the WBGT. c) The rise of the WBGT to its maximum is quicker than the drop thereafter. This is a consequence of the condition outlined above and is not characteristic for the entire tropical zone.

The mean values represent the reality only to a certain extent, insofar as the drop after the maximum is frequently quite pronounced, especially when the clouds produce rain. However, this drop occurs at different hours of the afternoon, so that this presentation of mean values obscures the abruptness of daily changes.

Figure III-4 shows the diurnal variations in WBGT index for five particular days, and their average. The average drop of the individual curves is 10°F; but the shift in the time of the maximum reduces the drop to 5°F in the five-day average and to a smooth, gradual decrease in the monthly mean. The curves show that the WBGT frequently rises again after the sharp drop in the early afternoon. This effect is produced by a "recovery" after the storm: the sun breaks through the clouds, the wind has died down, and the air is very moist because of the rain just fallen. The lack of wind is the essential factor. Therefore, the mean hourly WBGT in May-June is not lower than in the dry season although the latter has more sunshine. Actually it is higher, due to the higher wet bulb temperatures in the wet season. The monthly means for all daytime hours of the WBGT index show an unexpectedly strong parallelism in the annual variations for both stations (Table III-1.) The differences between them oscillate between 2.5°F and 3.1°F, and there are indications (its seasonal behavior, for example) that this oscillation is only random.

This relatively constant excess of 3 F for the open over the forested site points to a basic shortcoming in the method of obtaining this type of temperature index. On walking from the open into the forest a person actually feels cooler, but gradually he becomes more and more bothered by a feeling of warmth or oppressiveness, and after some time he will feel more comfortable in the open. The reason is in the way the human body functions. Any thermometer in the tropical forest (as for any of the three in the WBGT instrumentation) readily comes into equilibrium with the surrounding air, since temperature changes slowly and radiation effects are negligible small. The human body, however, generates heat and humidity of its own which, trapped to some extent by clothing, is not dissipated by air movement in the calm forest. As a consequence, after a short time of adaptation in a tropical forest, the human body attains a higher temperature and a higher moisture than the WBGT thermometers. This is to a certain extent also true in houses, while in the open there is generally enough air motion



WBGT VARIATIONS
FOR FIVE INDIVIDUAL DAYS

FIGURE III-4

to remove most of the excess body heat.

TABLE III-1. MONTHLY MEANS OF WBGT INDEX AT 0600 THROUGH 1900

	J	F	M	A	M	J	J	A	S	O	N	D
Chiva Chiva	80.1	79.8	79.2	80.5	80.7	80.4	80.9	80.1	80.2	79.6	78.8	79.6
Albrook	77.3	76.8	76.4	77.9	78.2	77.5	77.8	77.4	77.2	76.8	76.2	76.7

Though the WBGT index of the open site is closely correlated to that of the site in the forest, the correlation between the index variations and the season is not that simple. This occurs because all three temperatures enter the index with the same sign and different weight, while in the course of the year the variations of the wet bulb temperature are usually opposite to those of dry bulb and black globe temperatures. As a strange consequence we find that both the highest and the lowest means occur in the rainy season. Table III-1 shows that May is the month with the highest WBGT index. This occurs because a high wet bulb temperature coincides with a relatively large amount of sunshine and little wind. At the end of the rainy season the wet bulb temperature begins to drop to its dry season low before the dry bulb and black globe temperatures begin to climb to their dry season high. This produces a low WBGT index in November followed by a moderate high in January. In essence, the somewhat strange annual variation of the WBGT index is due to the fact that the change of seasons occurs at different times for different weather elements. This encompasses problems that are worth further study.

The Human Factors Engineer has a special interest in the frequency with which certain WBGT values are exceeded. Table III-2 shows how frequently certain thresholds were exceeded during a 29-month period (12,382 observations from 0600 through 1900) at the Albrook Forest Site. The absolute maximum was measured at 86°F in May 1965. When the data were compiled it was noted that all values above 85°F occurred at the beginning of the period. This is probably due to destruction of some of the vegetation by the construction of the tower. When using Table III-2 it should also be considered that the Albrook Forest is semievergreen and not very dense so that some sunshine always reaches the ground, especially in the dry season, and raises the dry bulb and black globe temperatures higher than would be typical for denser rain forests.

The comparison of the WBGT measurements accomplished under the Data Base project with those made at other Canal Zone locations (Fort Sherman and Gun Hill) by the Meteorological Team of the US Army Electronic Command, Meteorological Support Activity, Fort Huachuca, is planned for the future.

TABLE III-2. FREQUENCY OF HIGH WBGT INDICES IN ALBROOK FOREST BETWEEN 0600 and 1900

WBGT equal to, or exceeding	80°	81°	82°	83°	84°	85°	86°
Frequency in percent	17.4	8.4	3.0	0.72	0.36	0.04	0.01

PART IV. SOILS AND HYDROLOGY

General

Previous semiannual Data Base reports[1,2] have covered the methods of collection and types of data collected. The data collection has been completed for the two main sites (Albrook and Chiva Chiva) and the three original satellite sites. Data obtained from these sites have been presented in the reports referenced above.

During the current reporting period, data were collected from a soil satellite site at Fort Kobbe. Its location and description were presented in an earlier report[3].

Data

A summarization of data collected from the Fort Kobbe soil satellite site (and extending beyond the report period) is given in Tables IV-1, -2, and -3. No analyses of these data are presented for the current report.

TABLE IV-1. MOISTURE-STRENGTH, DENSITY SUMMARY
FORT KOBBE SATELLITE SITE 2, PLOT A

Date	Cone Index 0-6"	Cone Index 6-12"	Cone Index 12-18"	Remolding Index 6-12"	Rating Cone Index (Average)	Soil Moisture % Dry Weight 0-6"	Soil Moisture % Dry Weight 6-12"	Soil Moisture % Dry Weight 12-18"	Dry Density (lbs per cu. ft) 0-6"	Dry Density (lbs per cu. ft) 6-12"	Dry Density (lbs per cu. ft) 12-18"
1 Aug 67	71	150	351	1.08	161	28.2	26.6	30.9	84.7	86.1	78.2
8 Aug 67	114	170	282	-	-	25.8	25.0	29.7	81.2	92.3	84.5
16 Aug 67	93	173	308	-	-	28.4	26.9	30.6	82.7	89.1	87.9
22 Aug 67	70	155	333	0.97	150	29.2	25.8	33.1	84.4	92.5	85.5
29 Aug 67	146	-	419	1.24	103	24.4	24.1	27.8	84.7	86.2	-
5 Sep 67	87	160	309	1.11	179	26.8	24.9	29.3	84.8	91.3	-
6 Sep 67	121	138	146	0.83	116	24.7	27.9	31.4	88.0	88.9	88.9
12 Sep 67	68	115	266	0.99	122	27.2	26.8	31.7	87.4	91.8	95.2
20 Sep 67	77	184	362	1.02	185	28.8	28.5	32.2	83.7	87.5	91.9
26 Sep 67	158	281	382	0.89	251	23.5	23.4	26.5	85.3	88.7	97.6
3 Oct 67	120	227	367	1.01	219	26.3	23.7	29.0	87.5	92.6	90.2
10 Oct 67	51	124	311	2.67	300	29.7	39.0	28.4	79.7	90.2	84.3
11 Oct 67	85	144	208	0.69	203	30.1	31.4	35.4	82.9	82.0	82.6
17 Oct 67	176	280	362	-	-	22.4	25.3	28.4	84.0	85.5	90.1
24 Oct 67	157	280	412	1.06	294	22.8	21.4	24.0	76.9	92.0	94.0
31 Oct 67	67	125	272	0.95	113	28.6	25.9	30.3	83.7	90.6	84.7
1 Nov 67	66	103	159	-	-	25.6	28.4	32.8	90.3	92.3	92.5
7 Nov 67	82	183	398	0.92	447	29.9	26.5	29.6	83.6	-	-
14 Nov 67	65	165	348	0.98	159	31.1	29.6	40.6	86.6	91.0	75.5
21 Nov 67	103	198	308	1.02	113	27.4	23.2	26.0	82.9	93.7	93.2
29 Nov 67	72	121	321	1.01	120	30.1	26.4	28.0	83.1	92.3	92.9
5 Dec 67	104	217	336	0.92	177	28.3	25.8	30.4	87.3	90.9	86.1
12 Dec 67	57	125	266	1.01	129	30.5	30.5	40.5	86.0	85.5	74.2
19 Dec 67	119	227	357	-	-	28.4	27.9	33.0	82.1	92.0	86.3
26 Dec 67	97	159	229	0.91	153	27.6	26.2	27.7	83.9	94.9	93.1
3 Jan 68	152	296	518	-	-	25.8	25.2	29.0	83.9	89.5	-
9 Jan 68	264	378	458	-	-	21.4	22.4	23.2	81.3	88.6	83.0
17 Jan 68	404	634	666	-	-	17.0	18.8	24.7	83.4	-	-
23 Jan 68	472	700	750	-	-	16.4	20.2	22.7	-	-	-
30 Jan 68	421	724	750	-	-	15.8	17.7	19.2	-	-	-
23 Jul 68	160	309	484	1.08	225	23.3	22.2	26.9	87.5	-	-
31 Jul 68	137	294	517	-	-	24.3	20.7	25.5	88.3	-	-
22 Aug 68	228	490	594	-	-	23.1	23.0	26.9	-	-	-
30 Aug 68	152	393	623	-	-	23.8	20.1	21.2	-	-	-

TABLE IV-2. MOISTURE-STRENGTH, DENSITY SUMMARY
FORT KOBBE SATELLITE SITE 2, PLOT B

Date	Cone Index 0-6"	Cone Index 6-12"	Cone Index 12-18"	Remolding Index 6-12"	Rating Cone Index (Average)	Soil Moisture % Dry Weight 0-6"	Soil Moisture % Dry Weight 6-12"	Soil Moisture % Dry Weight 12-18"	Dry Density (lbs per cu. ft) 0-6"	Dry Density (lbs per cu. ft) 6-12"	Dry Density (lbs per cu. ft) 12-18"
9 Aug 67	64	99	132	-	-	30.1	29.5	29.9	85.3	90.7	88.1
16 Aug 67	72	94	143	-	-	29.7	31.6	32.9	83.1	83.7	86.3
17 Aug 67	42	38	40	-	-	40.6	44.1	52.4	70.9	74.2	69.1
21 Aug 67	89	119	161	-	-	29.0	30.7	30.0	88.0	84.3	85.6
23 Aug 67	116	159	209	1.32	207	28.5	30.0	32.8	86.1	86.6	81.7
30 Aug 67	230	300	360	0.94	280	19.1	21.4	27.4	84.3	91.6	87.1
7 Sep 67	35	31	22	-	-	37.9	49.7	55.5	78.0	68.4	66.4
13 Sep 67	61	145	245	0.98	377	31.7	31.3	32.7	80.4	81.0	81.8
21 Sep 67	80	137	253	1.03	140	28.0	29.5	30.6	83.0	80.0	69.9
27 Sep 67	192	281	299	-	-	21.0	22.4	24.8	78.3	82.7	-
4 Oct 67	109	222	228	-	-	32.1	29.6	31.6	78.4	86.2	-
18 Oct 67	236	262	223	-	-	19.5	24.1	31.0	86.8	89.0	84.3
25 Oct 67	297	439	388	-	-	20.6	22.0	26.5	80.7	84.2	88.0
8 Nov 67	75	135	155	-	-	29.8	30.3	36.1	86.8	86.1	80.8
15 Nov 67	84	126	157	1.49	194	31.9	32.2	31.4	82.9	85.0	84.3
30 Nov 67	61	116	148	1.08	127	31.6	30.5	32.3	85.1	86.1	85.1
6 Dec 67	63	122	203	0.99	144	29.8	32.3	33.4	85.1	85.0	83.7
13 Dec 67	55	99	223	0.80	82	33.3	30.9	30.3	82.2	87.0	85.1
20 Dec 67	63	105	149	0.92	95	29.3	29.2	31.3	84.4	90.2	90.4
27 Dec 67	103	142	178	0.98	140	27.7	31.6	33.5	86.6	81.1	80.4
4 Jan 68	148	165	178	-	-	25.7	28.8	32.1	80.4	82.5	82.9
10 Jan 68	289	378	390	-	-	19.0	23.9	26.4	80.8	79.0	83.2
18 Jan 68	405	589	619	-	-	19.5	23.5	26.8	-	-	-

TABLE IV-3. MOISTURE-STRENGTH, DENSITY SUMMARY
FORT KOBBE SATELLITE SITE 2, PLOT C

Date	Cone Index 0-6"	Cone Index 6-12"	Cone Index 12-18"	Remolding Index 6-12"	Rating Cone Index (Average)	Soil Moisture % Dry Weight 0-6"	Soil Moisture % Dry Weight 6-12"	Soil Moisture % Dry Weight 12-18"	Dry Density (lbs per cu. ft) 0-6"	Dry Density (lbs per cu. ft) 6-12"	Dry Density (lbs per cu. ft) 12-18"
5 Aug 67	55	69	57	--	-	33.3	39.1	49.9	77.9	77.2	72.4
24 Aug 67	53	55	32	--	-	36.8	46.5	51.1	77.2	71.2	65.1
1 Sep 6;7	33	26	25	--	-	43.9	53.2	51.4	74.0	66.3	68.7
8 Sep 67	16	12	11	--	-	-	-	-	-	-	-
22 Sep 67	41	41	23	--	-	37.7	50.3	55.7	76.7	71.7	68.5
5 Oct 67	36	29	23	---	-	38.9	48.0	56.3	75.3	71.5	64.9
12 Oct 67	37	34	30	--	-	46.5	55.8	64.5	69.6	68.1	73.5
27 Oct 67	9	11	10	--	-	-	-	-	-	-	-
11 Jan 68	40	37	30	--	-	43.5	40.7	51.1	70.3	76.4	70.1
25 Jan 68	58	39	35	--	-	37.7	48.4	52.0	77.2	72.3	77.3
16 Feb 68	44	35	27	0.53	19.2	50.3	63.4	60.6	-	-	-
21 Feb 68	38	28	21	0.85	24.0	44.7	59.0	55.2	72.1	-	-
28 Feb 68	34	22	18	1.59	34.9	41.1	55.6	59.6	74.1	-	-
6 Mar 68	48	38	35	1.12	41.9	39.6	48.4	59.6	75.2	-	-
20 Mar 68	60	64	58	1.70	108.6	36.5	40.1	48.4	78.8	73.7	
22 Mar 68	57	53	52	1.11	58.6	37.3	40.1	57.3	78.3	75.4	-
27 Mar 68	58	47	33	1.25	58.3	39.2	45.6	54.2	76.1	74.4	-
29 Mar 68	64	53	33	1.31	82.3	39.3	43.9	52.3	75.3	73.9	-
3 Apr 68	66	68	46	0.83	56.3	41.8	45.1	50.6	74.5	73.3	50.6
5 Apr 68	52	45	42	0.93	41.9	42.1	45.0	55.2	74.4	72.6	68.7
10 Apr 68	50	52	42	1.01	52.7	41.2	41.5	50.7	76.4	76.2	70.8
11 Apr 68	52	48	46	1.21	58.1	41.6	44.3	53.6	75.8	75.8	69.1
19 Apr 68	54	53	50	0.78	41.2	39.0	38.9	46.2	79.1	79.7	76.3
24 Apr 68	63	62	52	0.81	50.0	37.7	40.7	49.[illegible]	78.6	75.8	72.4
25 Apr 68	61	54	59	1.11	60.7	37.3	39.2	42.7	79.2	79.6	-
1 May 68	61	62	55	0.93	57.4	36.0	38.8	46.1	81.2	77.1	46.1
8 May 68	48	43	42	1.01	43.7	36.7	4[illegible].2	53.1	81.4	-	-
16 May 68	47	48	45	0.79	38.2	42.4	[illegible]1.1	52.3	76.7	74.7	-
23 May 68	62	45	50	0.79	35.3	36.9	43.9	51.1	80.6	77.4	-
29 May 68	58	66	47	0.94	62.0	37.6	43.6	51.3	80.0	79.1	-
5 Jun 68	55	40	100	0.98	39.[illegible]	3[illegible].5	48.0	64.2	-	-	-

PART V. VEGETATION*

Introduction

Earlier semiannual reports on the Data Base Project presented descriptions of the vegetation at the Albrook Forest site in the form of vegetation inventories of a 3,600-square-meter gridded area. The most recent semiannual report discussed the floristics of the site, with special emphasis on plant succession. The authors have recently studied plant associations on additional sites. Information gathered at other locations now allows a more detailed analysis of the exact place in the succession that is occupied by individual plant species.

Background and Discussion

The difficulties inherent in describing associations of tropical plants were discussed in previous reports. To recapitulate briefly: it is necessary to identify the major plant components on the site, then the physical parameters must be measured, and finally a designation of type, or general descriptive term for this assemblage of plants must be made. Obviously, the terminology employed must be consistent with ecological literature, so that large units, all over the work, can be compared. For example, mangrowe swamp forest is an acceptable term, while white mangrove Brownea - Achrostichum association is probably too specific. The problem lies in the fact that a true climax association is rarely encountered in the Central American tropics. The element of time is added, and the ecologist must know the history of the association, in order to extrapolate the future vegetal development of the site. In order to accomplish this task, theoretically each plant ecologist should be expected to know all the plant species, and all possible associations. There are too many plant species to do this; in some tropical associations over 200 woody species occur (Richards[7]).

Where data are available, the total plant association may be classified by the designation of indicator species. These are species which, by their presence (or sometimes absence), furnish significant clues to the status of the remaining association. The optimal condition would be met when the smallest number of indicator species would provide maximal information about the most complex plant associations. The selection of such indicators is not always simple, and in large part should conform to the following standards:

1. It must be a common plant, preferably easily recognized. Obscure and rare plants might be excellent indicators, but could be overlooked by the casual collector.

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* This section has been prepared by Dr. Thomas C. Crebbs, Jr., Research Biologist and Dr. Robert S. Hutton, Biological Scientist

2. It should be restricted to a narrow range of climatic or edaphic conditions. If it flourishes in profusion on many sites, then it cannot be used as an indicator of such distinctions as, for example, available soil moisture, fire, or salinity.

3. Its genetic potential should be well understood. Size, age, thrift, crown development, time of flowering, life span, light tolerance, all must be known in order to determine what exact role the indicator species plays in the overall plant association. Simply, the observer must be able to determine if a species is becoming established, or is merely a remnant in an association.

4. It must be more definitive as an indicator when occurring with other indicators than as an isolated specimen. This means that a plant, species X, which may or may not be definitive as a canopy dominant, definitely and conclusively becomes an indicator of dominance when associated with indicator species Y and Z.

The following list of plants have been found valuable as indicators within the Panama isthmian area:

Anacardium excelsum (Bert & Balb.) Skeels (Anacardiaceae)
(Espave, wild cashew). One of the largest trees in Panama, to 36 m high, 130 cm DBH*. Seedlings are light-intolerant, only invade after woody succession is well-advanced. Presence of medium-sized individuals indicates advanced succession, large individuals are remnants of earlier forest, old pasture, or if numerous, climax forest.

Spondias mombin L. (Anacardiaceae)
(Jobo, hogplum). Small tree to 17 m high, 45 cm DBH. Light tolerant as seedling and adult, a common component of young second growth edge around clearings. Soft-wooded and short-lived, it does not persist under heavy canopy. Indicates succession of less than 100 years, unless site is dry, with open canopy, where it may persist.

Spondias purpurea L. (Anacardiaceae)
(Jobo, Spanish plum). Shrub or small tree to 9 m height,28 cm DBH. Very shade intolerant, occurs in open fields and brushy hillsides, favored for living fenceposts. Indicator of dry site and/or infertile site. Makes best growth in sandy soils.

Luehea seemanii Triana + Planch (Tiliaceae)

Luehea speciosa Willd (Tiliaceae)
(Guacimo Luehea). The two Lueheas are grouped, because they indicate an almost opposite forest type. L. seemanii is a forest giant,

* DBH = Diameter at breast height.

to 34 m high and 120 cm DBH, occurring in older forests, especially on drier sites. L. speciosa can become a large tree, but flowers as a shrub, and is common in thickets of the Pacific slope. The presence of L. speciosa, of small stature and in numbers, indicates young second growth. L. seemannii is a secondary invader, rarely appearing before 35-40 years of invading vegetation have been established.

Apeiba tibourbou Aubl. (Tiliaceae)

(Cortezo, monkey comb). Cortezo is a small tree, sometimes reaching a height of 12 m. which is found either as open-grown individuals; as a bush on areas repeatedly burned over or along edges between grassland and forest. Both Johnston[8] and Blum[9] have noted the repeated occurrence of cortezo on burned-over areas, though it is not restricted to such. It is quite shade-intolerant, never occurring under or as a component of forest canopy. A pioneer species, it indicates continous exposure of the site to full sunlight, a young (less than 40 years) association, and is quite resistant to fire. It coppices readily, and may do so after being fire scarred.

Byrsonima crassifolia (L.) H.B.K. (Malpighiaceae)

(Nance). This small tree (to 9 m) is included here because it is often found as an associate of cortezo. Unlike cortezo, it forms low forest in areas composed almost entirely of this species. When found with cortezo, its growth habit is bushy, and rarely over 4.5 m high. The two almost positively indicate repeated burning, and are usually present in numbers on Pacific slope grasslands which are burned annually. A thorough discussion of the effects of fire in this association can be found in Blum[9]. Nance is primarily an indicator of dry and/or infertile sites, which may or may not have been changed by fires. In areas where the upper soil horizons have been removed; Nance is a primary invader, and is often the only woody plant to persist.

Gustavia superba (H.B.K.) Berg (Lecythidaceae)

(Membrillo, Gustavia). This small tree (to 15 m) is one of the common trees of wet forests, especially on the Atlantic slope. Standley[10] recognized the wet aspect of this species, and Kenoyer[11] accurately named it as an invading species at from 15-50 years. Thus Gustavia, which is shade tolerant, is a secondary invader, indicating a wetter site (or perhaps sites where annual rainfall is well distributed) and an intermediate or advanced stage in forest succession. It persists and reproduces under the canopy of taller trees, so can be a climax associate.

Cecropia longipes Pittier (Moraceae)

C. obtusifolia Bertol

C. peltata L.

(Guarumo, Trumpet-tree). One of the most abundant and conspicious trees of the area, Cecropia species are so shade intolerant that they rarely become successful unless a removal of existing vegetation has occurred

by some process. A small-statured genus, rarely exceeding 21 m high and 45 cm DBH, these trees are extremely fast-growing but short-lived. Most species seem to produce a heavy fruit crop annually, which is bird disseminated over wide areas. Blum[9] found the upper layers of second growth forest soil "loaded" with Cecropia seeds, which germinated from 32 to 97 percent better in light than in darkness. This dependence upon openings for successful establishment makes young Cecropia excellent indicators of recently disturbed sites. When older individuals occur in forest associations, they cannot be reproducing, so indicate a secondary sere. Solitary individuals, dead or dying, found in older forests indicate the end of the secondary aspect of a forest, and an approaching climax condition, dependent upon other indicators on the site.

Didymopanax morototoni (Aubl.) Decne & Planch, (Araliaceae) (Mangabe, matchwood). Matchwood attains a height of 30 m., but is usually much shorter, with a slim bole. Similar to guaramo in that it is a pioneer on disturbed sites, it differs markedly in its persistence. It is not a component of mature forests, being unable to reproduce under shaded conditions, so becomes a good indicator of forests approaching climax. Its presence in forests with tall dominants indicates that the site was at one time cleared, and that is has been vegetated for approximately at least 80 years.

Ochroma pyramidale (Cav. ex Lam.) Urban (Bombacaceae) (Balsa). Balsa is best-known as one of the lightest of woods; it is also one of the fastest-growing. It has been known to reach 20 meters in 6 years, or better than 3 m per year. It is extremely intolerant of shade, and only becomes established on open soil, where it often forms a thicket of even-aged seedlings (Johnston[8]). It does not persevere to form forests, and is found here as a large tree only when planted for shade, or along roadsides. An excellent indicator of recent bare-soil conditions when young, and of less recently cleared land when of sapling size.

Terminalia amazonia (J.F. Gmel) Exell (Combretaceae) (Amarillo real). Terminalia grows to great size, often over 30 m high and 125 cm in diameter. It is common forest dominant, especially in Pacific slope forests and can be found in several different forest types. Very little is known about light conditions for favorable germination and growth of seedlings, but they are rare in cleared or second-growth areas. Small-statured trees of this species are not found as associates of other indicators of young second-growth stands; for this reason Terminalia is considered to be an indicator of climax or near climax forest associations.

Socratea durisssima (Oerst.) Wendl. (Palmaceae) (Jira, stilt palm). This palm is almost entirely restricted to the Atlantic slope. One of the few palms that are truly indicator species, it is common on moist sites as a component of mature forests. Kenoyer[11] lists this palm as a forest dominant, but he means it is usually found in older forests; its 23 to 25 m height does not allow it to reach into the canopies of the true dominants. Very shade tolerant, it probably does not

reproduce unless under shaded conditions. The presence of this palm in numbers indicates a moist climax forest association, or one approaching a climax state.

Bursera simaruba (L.) Sarg. (Bursaraceae)
(Jinote, almacigo, gumbolimbo). This small (to 12 m, 5 cm DBH) tree is a typical component of Pacific slope second-growth forest occurring on drier sites. It is not restricted to dry sites, but when it is found abundantly, the site is on well-drained soil, rocky or shallow. It is not found in mature forest associations. It coppices readily and may form thickets when cut.

Cochlospermum vitifolium (Willd.) Spreng. (Cochlospermaceae)
(Poroporo). A quite small tree, to 8 m high and 25 cm DBH, this showy, yellow flowered species occurs only in young second growth associations. It is most shade intolerant, so pioneers in grasslands and on disturbed sites. Openings caused by fire in grass are often invaded by this plant. It does not persist in any association that passes it in height, and is often found unthrifty or dead in second-growth that has overtopped it. This condition probably occurs less than 20 years after the overgrown site has been disturbed.

Enterolobium cyclocarpum (Jacq.) Griseb. Leguminosae
(Corotu, eartree). A very large tree, to 3 m diameter and 40 m high, eartree cannot really be termed a forest species. It seems to be relatively shade intolerant, especially in the seedling stage, and is most commonly found growing as individual specimens in pastures. When pastures are allowed to return to a forested condition, the large eartrees remain as relict species. Therefore, in a mature forest they are good indicators that the site was once pastured. Blum[9] considers that the single large eartree on the Albrook Forest site did not develop with the vegetation present there now, but is a relict from a time when the site was in pasture.

Many other species occur in association with these indicator species, and doubtless many of them will prove of value as indicators when better known ecologically. With these few indicator species, a great deal of information can be garnered by a superficial examination of a site. A few examples, taken from locally extant associations, may serve to illustrate the utility of these indicator species for drawing significant and reliable inferences on the history and conditions of the stand.

(1) Cecropia peltata. Few individuals, poor thrift, no reproduction.

Terminalia amazonia. Few individuals, medium stature.

Enterolobium cyclocarpum. 2 plants large size.

Spondias mombin. Scattered large size, poor thrift.

This site was at one time an open field or pasture. Spondias and

Cecropia persist as primary invaders, but the presence of Terminalia indicates the approach of a climax forest type. The Enterolobium is a relict. The age of this forest is probably 80 to 100 years.

(2) In a sparse, open grassland, many Nance are found, interspersed with monkey comb and gumbolimbo. No other tree species occur.

The area has been repeatedly burned. Further, it is dry, rocky, infertile, extremely well-drained, or a combination of these.

(3) In an Atlantic slope forest, the upper story is composed of many tree species. No espave, membrillo, or stilt palm occur in the upper canopy, but all three species are found on the site, as medium-statured individuals.

This site is moist, receiving moisture nearly all year. Whatever the canopy species, they are not climax associates, and will be replaced by the indicator species. A secondary forest, probably 100-120 years of age since last disturbed.

(4) A site supports a low canopy of Cecropia, through which occasional small individuals of Luehea speciosa, balsa and Spanish plum emerge. A few unthrifty poroporo also occur.

This is a second-growth association that has developed on a cleared or burned over site. The living poroporo indicate that it has been vegetated for less than twenty years. The site is probably dry and infertile.

These examples serve to show what inferences may be made by the use of indicator species. As more are added to those in use, forests may be typed and aged, mineral formations located, and past land use elucidated with a minimal amount of field study.

PART VI. MICROBIOLOGY AND CHEMISTRY OF THE ATMOSPHERE*

Introduction and Background

The first semiannual report[1] (paragraphs 134-187) cited five types of investigations involving biology and chemistry of the tropical environment. These included investigations of deposition of microorganisms on surfaces, observations on distribution of airborne microorganisms, chemical content of the atmosphere, the role of microorganisms as sources of atmospheric contaminants, and observations on condensate nuclei and particulate matter. In a subsequent report[2] further observations on the qualitative and quantitative character of microbial populations in the environment were reported and parallel information on soil microbes was provided. In still another report[3] the presence of carbon dioxide in the forest atmosphere was examined in some detail. The investigations of airborne and surface deposition of microorganisms have been continued through the present period. A paper (Hutton[12]) presenting and interpreting some of these data is to be published in 1968. These data, and data collected subsequently, will be processed and presented in full in a later semiannual report and will be available for analysis and use by ourselves and others. Similarly, chemical observations were continued, with the assistance of members of the staff of the National Center for Atmospheric Research (ARO Contract DAH CO4 67 C0024), and these data are also being processed to make them available for later publication and analysis. Observations of condensate nuclei, made originally, were not continued because major problems were encountered with keeping instruments operable in the tropical environment. On the other hand, observations of particulate matter in the atmosphere were increased and these data are being prepared for future publication and analysis.

In this report data will be presented to illustrate not only that microorganisms contribute to the chemical contamination appearing in tropical atmospheres but also to show that they have what may be an important role in the withdrawal of chemical contamination from the atmosphere. The data will also be presented in a way intended to show that microorganisms acting on reactive chemical volatiles may influence materials exposed and in use in the environment.

Very early in our investigation (see reference[1], paragraph 137), we noted that surfaces of materials exposed in the environment tend to acquire a heavy layer of contamination by foreign matter and microorganisms. This contamination occurs so rapidly that the property of being biologically inert, sometimes attributed to inorganic materials and the less reactive plastics, can properly be questioned. Reported inabilities to correlate the results of materials failure in exposure tests between real and simulated (chamber) tropical environments may be associated with

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* This section has been prepared by Dr. Robert S. Hutton, Biologist.

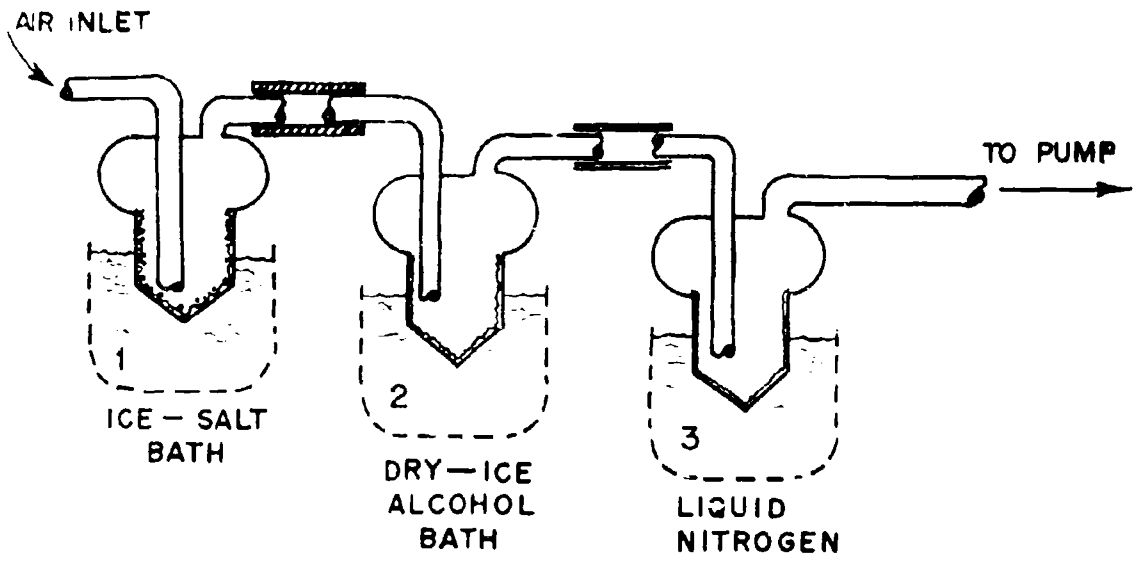
the fact that, in a simulated tropical environment, contamination of surfaces is not normally heavy and debris accumulates slowly if at all. These facts provide a rationale for a re-examination of the tropical environment in order to characterize its unique elements or features and/or to describe and detect quantitatively the factors responsible for the corrosive and degradative reactions observed to occur there.

Work leading to the observation that concentrations of volatile organic substances derive from microorganisms growing in association with plants (Reference[1], paragraph 179) was extended in a paper by Hutton and Rasmussen[13].

Analytical Methods and Results

The data presented in the present report were all collected with a Beckman GC-5 gas chromatograph equipped with a 6-ft long 1/8-in diameter Poropak Q column. Head-space air in flasks in which microorganisms were growing, and air having high concentrations of vapor were analyzed directly. Where concentrations of organic vapor were low, volatiles were collected, using first a conventional three-stage trap with ice, dry-ice, and liquid nitrogen supplied to the three stages. (Figure VI-1). Later a single stage liquid nitrogen cold trap, developed during the course of the work was used. (Figure VI-2). Details of development of the latter are not pertinent to this report; however, comparison of products of the two traps were essentially identical, and the single-stage trap was used as a matter of convenience and economy.

In addition to the chromatographic profiles of volatiles from atmosphere over leaf surfaces and representative fungal cultures already reported in (reference[2], paragraph 179), the atmospheric volatiles derived from wet wood shavings, other fungus cultures and forest air (direct and cold trapped) have been sampled. In very simple systems specific peaks, which can be reproduced at will in successive determinations to demonstrate a characteristic "signature", can be produced. For example, each of several native woods of Panama appears to have its own characteristic signature. Three such signatures of fresh wood shavings are shown in Figure VI-3. Also shown in the same figure are the profiles of signatures as they are altered as the woods become contaminated with fungi. In these and other observations the important thing to recognize is that a great variety of organic volatiles are present; and, while a particular combination of elements of the environment is certain to produce a characteristic signature, the ability of man to produce, exactly, a desired combination of these elements to produce a specific signature is limited indeed. For example, a characteristic "signature" of a freshly shaved wood specimen is altered as the shavings become contaminated with fungi. The nature of the alteration is dependent upon the contaminant or contaminants present, the length of time the contaminant has grown in culture and the degree of decomposition of the substrate present, the O_2 tension and temperature of the air bathing the system, the amount and reaction of the water present in the system, and in some instances even the wavelength and intensity of the



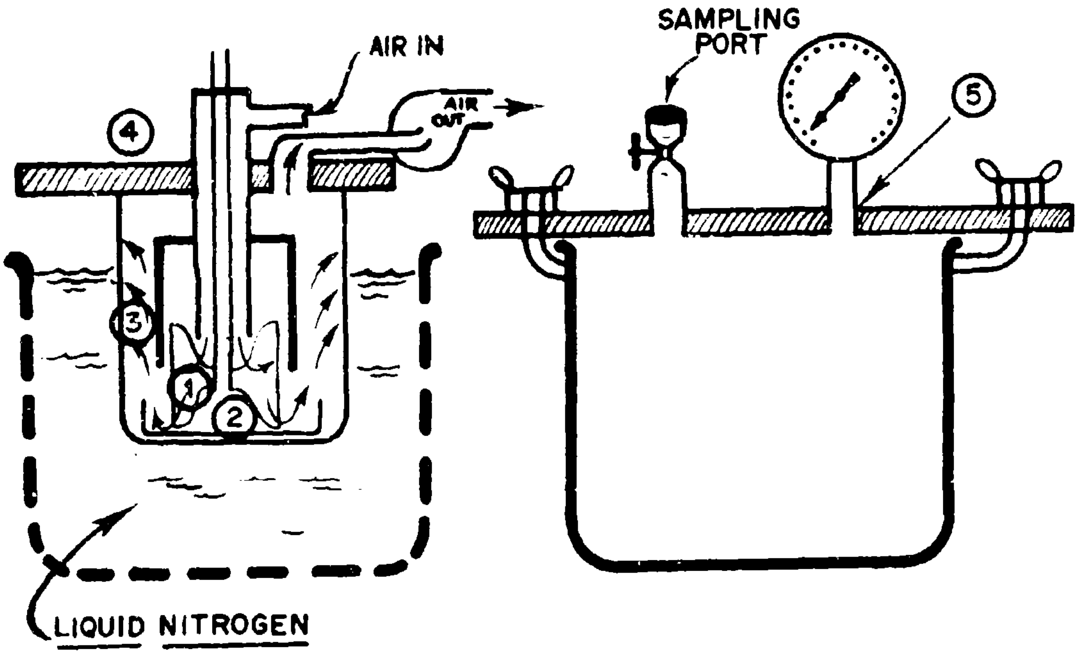
STAGE 1 (-10°C) REMOVES MUCH OF THE WATER FROM THE SAMPLED AIR.

STAGE 2 (-70° C) REMOVES REMAINING WATER AND SOME OF THE HEAVIER VOLATILE CHEMICALS.

STAGE 3 (-190°) CONDENSES THE LIGHTER VOLATILE CHEMICALS.

FIGURE VI — I

THREE STAGE COLD TRAP APPARATUS



HAND ROTATED SCRAPER (1) REMOVES CONDENSED FROST FROM INNER CHAMBER WALL. FROST THEN DROPS TO PAN (2) FOR LATER REMOVAL. VOLATILES ARE CONDENSED ON SURFACE (3) AT LIQUID NITROGEN TEMPERATURE. AT END OF COLLECTION INTAKE AND BLOWER APPARATUS (4) AND MOISTURE PAN REMOVED AND REPLACED BY COVER (5).

FIGURE VI – 2
SINGLE-STAGE LIQUID NITROGEN COLD TRAP

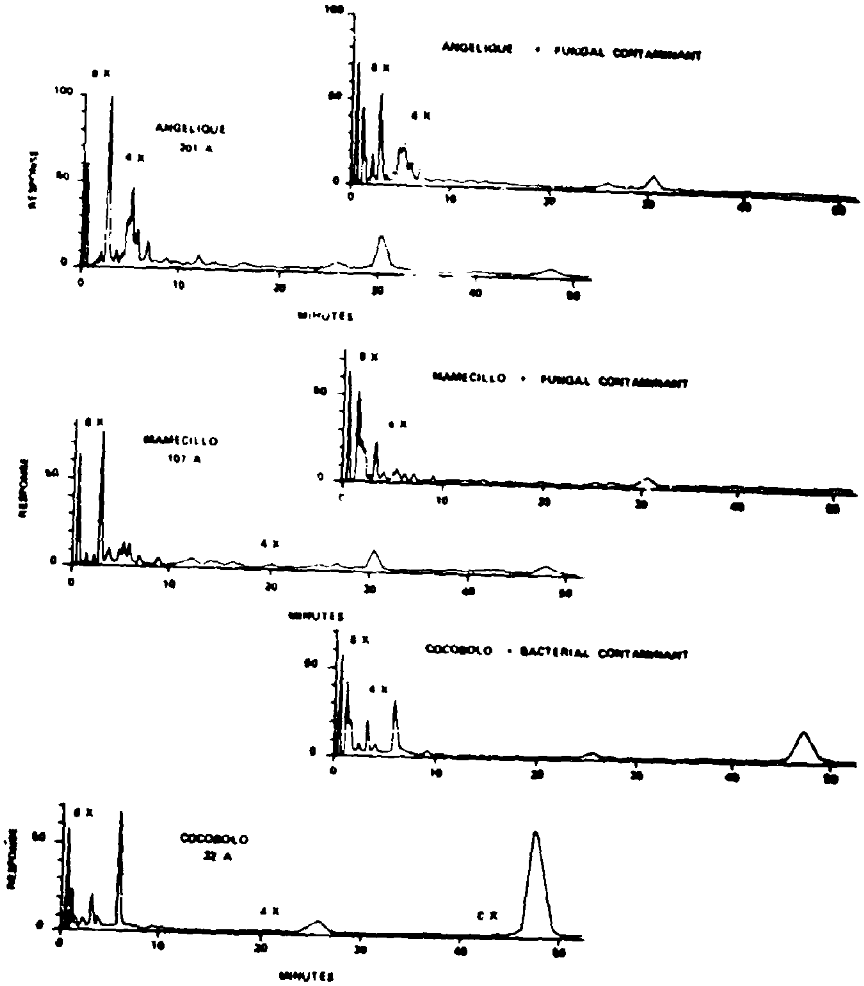


FIGURE VI-3. ATMOSPHERIC VOLATILES DERIVED FROM WET WOOD SHAVINGS

ambient light. Thus the purpose of this and the other illustrations to follow is to show that organic volatiles are present, that they do interact with the microbial forms present, and that the manner of interaction is dependent upon the "mix" of all the variables of the physical and biological environment.

Any material capable of being decomposed (or utilized) by microorganisms is apt to exhibit a demonstrable profile or signature. Figure VI-4 is a three-part chart which shows in A the profile of an uncontaminated medium (Sabouraud) used to cultivate fungi. The profile of a flask of the same medium a day later is shown in part B. At the time of observation the reason for the changed signature was not known, however, later observation revealed that the flask examined had been contaminated by a Penicillium species to a degree not discernible by eye or odor. The fact that even the slightest growth of a contaminant greatly altered and significantly reduced the quantity of volatiles present should be noted as it will be referred to later. The profile of another flask of a medium visibly contaminated by Monilia species is given in part C. The manner in which peak intensities of several genera of fungi vary with time is illustrated in Figure VI-5.

Without resort to more sophisticated analytical tools than were available, an absolute determination of the nature of the chemicals responsible for the peaks in the profiles shown above is not possible. A reasonable approximation of the nature of the peaks may be had, however, by comparisons of elution times of peaks in these samples with elution times of some known chemicals. In the range of time 2.9 to 57 minutes, during which most of the sample peaks examined here appeared, known chemicals appearing in near identical times coinciding with observed peaks are -pinene 2.9 min., B-pinene 4.5 minutes, phellandrene 5.9 minutes, d-limonene 7.4 minutes, cineol 7.8 minutes, -terpenine 11.2 minutes, linalool 25 minutes, and terpineol 57 minutes. Possibly several thousand other substances, many hundred of which are known to be biologically active and all the rest having unknown biological properties, would fall into this same range of elution times hence the peaks detected by the gas chromatograph provide only a rough guide to the probable weight and configuration of the molecules present as the actual contaminants in the samples.

In spite of the seemingly general and ambiguous nature of these observations, it becomes clear that they are relevant to practical problems when we note that the ambient atmosphere particularly in the tropical forest contains significant quantities of these volatile substances. The illustrations provided above show that volatile substances resulting from action of microbial forms on organic matter can contribute to air contamination. We next, undertook to determine whether such volatiles are present in tropical atmospheres. While direct sampling of forest air was possible, most of the observations of ambient air were made using the single-stage cold trap described above. Usually the volume of air from which the sample was drawn was about 2,000 liters. A significant increase in concentration,

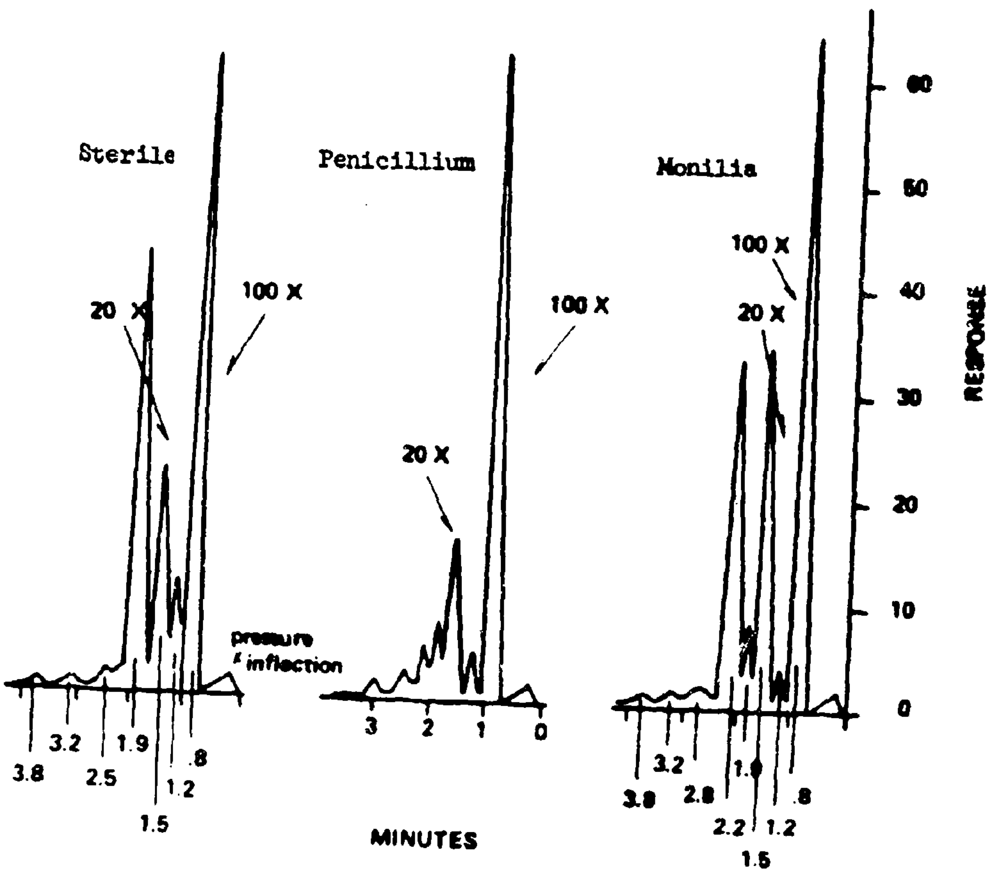
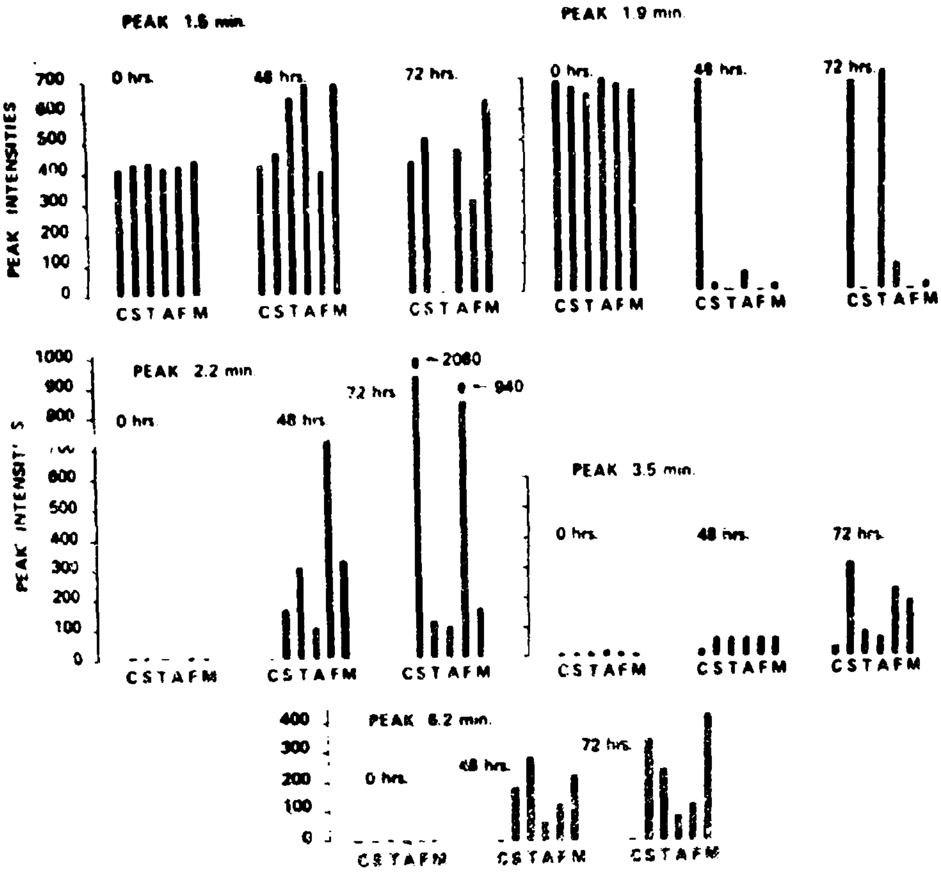


FIGURE VI-4. CHROMATOGRAM OF VOLATILE ORGANICS IN AIR OVER SABOURAUD-DEXTROSE AGAR



LEGEND:

C - Control
S - Streptomyces
T - Trichoderma
A - Aspergillus
F - Fusarium
M - Mixed

FIGURE VI-5. COMPARISON OF VARIATION OF CHROMATOGRAM PEAKS OF SEVERAL GENERA OF FUNGI WITH RESPECT TO AGE OF CULTURE

particularly of the lighter substances, was attained using the cold-trap technique. Figure VI-6 illustrates this. Using the cold-trap technique, samples of ambient atmosphere at ground level and in the low forest canopy were made. Figure VI-7 shows the higher concentration of volatiles in the air near the ground.

Based on the above it appears that: a) atmospheric volatiles are produced by microorganisms acting to decompose organic matter, and b) volatiles are, or can be, altered and probably removed from atmosphere by similar action on microorganisms (see above). The practical importance of this observation remains, however, to be made evident.

In an effort to illustrate how the volatiles in the atmosphere behave and how they might be able to exert an effect on surfaces and enclosed areas, the fate of volatiles in air inside closed containers was observed. Cold-trap volatiles were put in each of several closed containers. One pair of containers was held at constant temperature, one was subjected to cyclic temperature variation to bring the air alternately to a temperature above and below its dew point. One container of each pair was inoculated with fungi commonly found in the forest environment. Results of a representative experiment are presented in the following tabulation.

	Days of Storage in Container	Inoculated with Fungi (volatiles)*	(volatiles)*
Temperature Cycled	0	12,590	13,160
	4	2,410	3,990
	15	1,780	2,525
Temperature Constant	0	12,980	13,290
	4	10,230	14,600
	15	13,280	13,390

The rapid disappearance of volatiles, from the air in the enclosure in which temperature was cycled and fungi are present, is in keeping with the idea expressed above that volatiles present in air are condensed on surfaces as a result of naturally acting physical forces. For example, all surfaces exposed in the tropical environment become wet with dew many times each day. In the instances at hand, the volatiles are removed from the air only when the physical environment is manipulated (by temperature cycling) to permit the necessary conditions for removal to exist. Evidence that the air is more effectively made free of volatiles when fungi are

* Numbers are derived from measurements of peak areas and represent relative quantities of volatiles present.

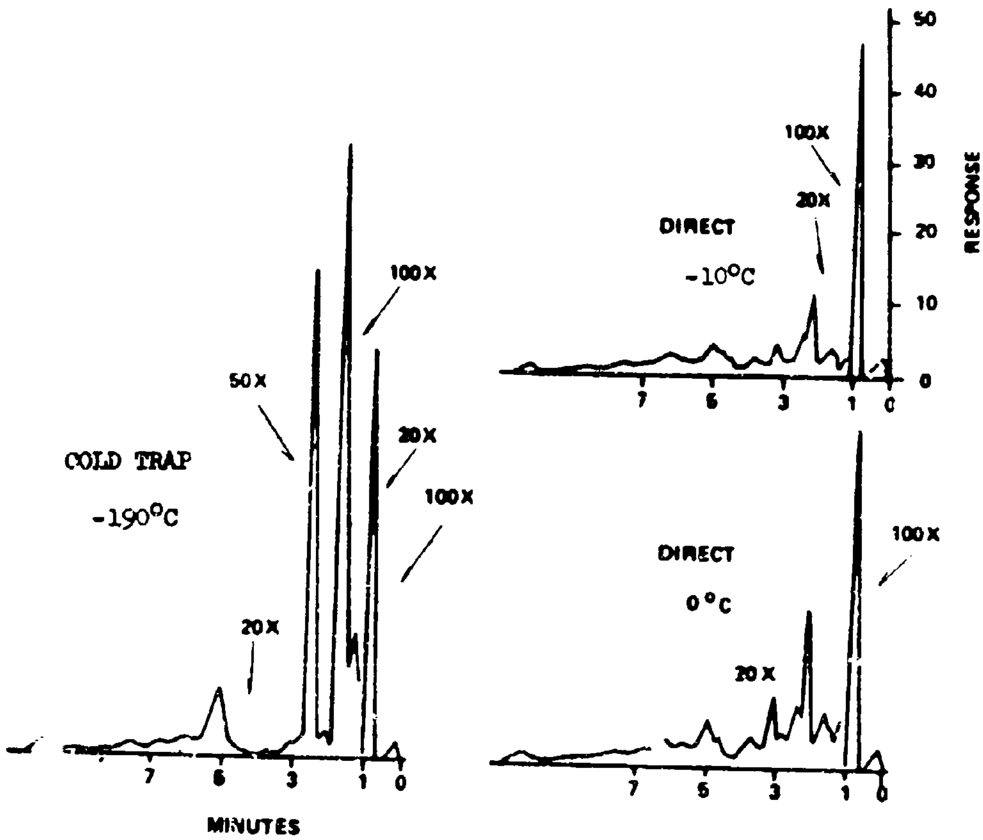


FIGURE VI-6. DIRECT VS COLD-TRAP SAMPLING OF ATMOSPHERE

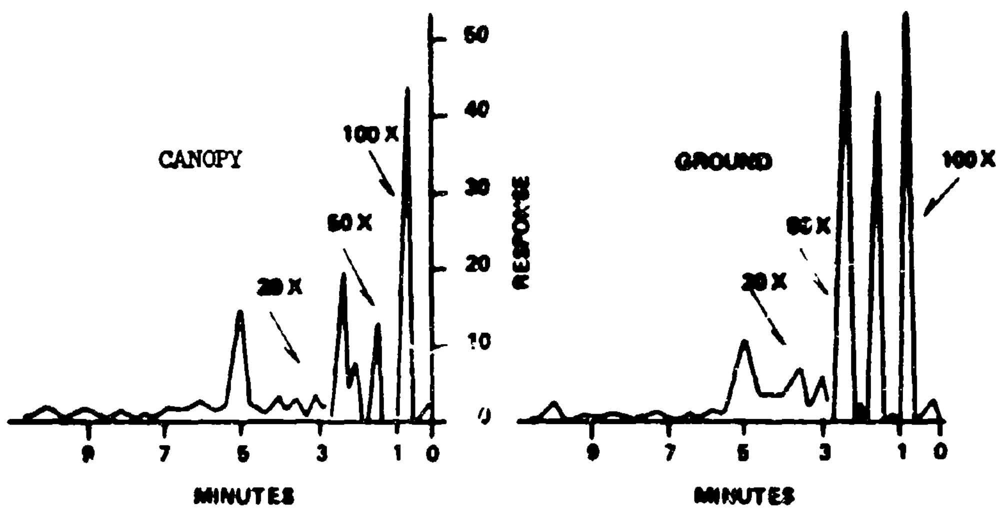


FIGURE VI-7. COMPARISON OF COLD TRAP CHROMOTOGRAMS MADE AT GROUND LEVEL AND AT TREE CANOPY IN ALBROOK FOREST.

present is less convincing. However, in these experiments no way was found to insure that the volatile products of the cold traps did not contain their own complement of microorganisms, hence, there is no assurance that any of the enclosures were free from microbial life. In other experiments in which chemicals similar to those found as cold-trap volatiles were held in sterile chambers and in inoculated chambers, the removal of volatiles was significantly greater in the inoculated chambers. (Hutton[14]).

Observations made during the course of testing material reveal that, generally, severe deterioration occurs on the inside surfaces of electronics black boxes, inside wholly or partly enclosed containers, inside gasoline tanks, and in most places where ventilation is restricted. Since corrosion and deterioration is more often found under the conditions which exist when removal of atmospheric volatiles from the atmosphere is at a maximum, it becomes reasonable to suggest the likelihood of existence of a cause and effect relationship. Observations related to the above and a discussion of cause and effect relationships involved in the area of tropical testing, materials failure, and performance of equipment in the tropical environment will be discussed in greater detail in a paper to be presented at the First International Bio-Deterioration Conference to be held 5-11 September 1968.

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13. ABSTRACT

This fifth semiannual progress report on the Environmental Data Base Project contains a brief background of the project, its objectives, approach, and sites of operation, and presents a summary of activities for the period September 1967 through February 1968, with some analyses and syntheses of selected data.

The Climate section (Part III) presents an analysis of the Wet Bulb Globe Temperature data.

The Soils and Hydrology section (Part IV) presents a summary of the data collected at the Fort Kobbe Satellite site.

The Vegetation section (Part V) contains a discussion and description of the utility of individual plant species as indicators of forest succession and development.

The section on Microbiology and Chemistry of the Atmosphere (Part VI) presents a discussion of the role played by microorganisms in the modification of chemical contaminants of the atmosphere and their potential effects on materials exposed to the environment.

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Soil Trafficability						
Tropical Vegetation						
Tropical Vegetation Succession						
Contamination in Tropical Atmosphere						
Microorganisms						